THE UNIVERSITY OF TEXAS AT AUSTIN

FINAL REPORT

Submitted to

The National Aeronautics and Space Administration

for

Satellite Ranging Data Analysis

under

LAGEOS A.O. No. OSTA 78-2

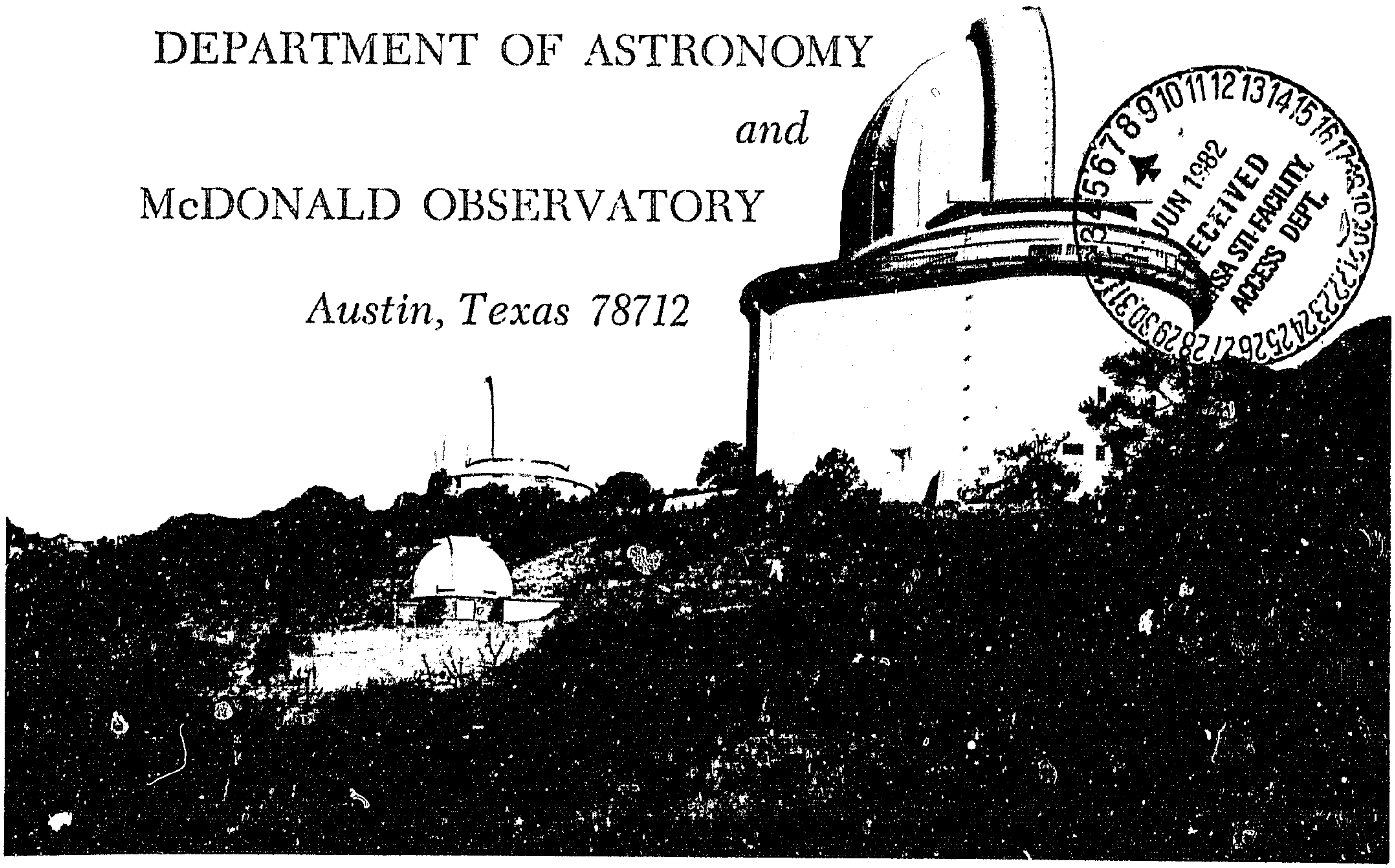
NASA Contract NAS5-25898

DEPARTMENT OF ASTRONOMY

and

McDONALD OBSERVATORY

Austin, Texas 78712



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Peter J. Shelus

Social Security Number [redacted]

Department of Astronomy and McDonald Observatory

The University of Texas at Austin

Austin, Texas 78712 USA

1981 December

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1. Introduction

NASA Contract NAS5-25898 entitled "Satellite Ranging Data Analysis" provided funding for the Department of Astronomy of the University of Texas at Austin under the direction of Dr. Peter J. Shelus, Principal Investigator, during the time interval 21 November 1979 through 20 August 1981.

The original proposal spoke to six basic tasks which were to be undertaken as part of the contract. Subsequent negotiations toward an acceptable Statement of Work gave high priority to two of the original six proposed tasks, i.e.,

- Task 1: Apply LAGEOS-derived polar motion components (x,y) to LLR data;

- Task 4: Using multi-station LLR data alone, compute values of Earth rotation components (x,y) and UT1.

Somewhat lower priority was assigned to two other of the proposed tasks, i.e.,

- Task 5: Relate LLR and LAGEOS reference frames;

- Task 6: Compare Earth rotation components as derived using LAGEOS and LLR data against each other and against other techniques.

Finally, the remaining two proposed tasks were not supported:

- Task 2: Using residuals of LAGEOS ranging data with respect to a well-defined model, compute values of Earth rotation components (x,y) and UT1;

- Task 3: Provide long-term calibration bench-marks for LAGEOS-derived UT1 values.

2. MERIT Campaign Back-Up Analysis Center

Under the subject contract, the University of Texas at Austin operated satisfactorily as a back-up Analysis Center (in addition to its role, under other funding, as a Computational Center) for the lunar laser ranging data type during the short MERIT Campaign which was held 1 August 1980 through 31 October 1981. The term "back-up" refers to the circumstance that we were not obligated to respond in near-real-time. Our responsibilities as back-up Analysis Center were to process LLR data gathered during the MERIT interval, subject it to suitable physical and mathematical modelling to produce a

UT1-UTC data product and to forward same to the MERIT Coordinating Center at the Bureau Internationale de l'Heure in Paris. Using a continually evolving system, designed for the extraction of Earth rotation information from the LLR data type (partially funded under this contract), this task was satisfactorily handled in a routine manner. The data file transmitted to the BIH and the text report which accompanied that data transfer is included as Appendix A of this report. An informal comparison was made among the various LLR UT-1 data products at IAU Colloquium No. 63 at Grasse, France last spring. The comparisons were startling in their agreements. A formal report of this comparison will be included in the Proceedings of the Colloquium which should be available soon. Also, the McDonald Observatory LLR UT-1 MERIT data set is available in machine readable form either from the Principal Investigator or from the BIH. Since the results outlined above can employ polar motion parameters other than those supplied by the BIH in their monthly Circular D mailings, they satisfy, in part, contract requirements under Task 1 of our original proposal.

Even though there was LLR data obtained from the Orroral Valley station in Australia, the data set forwarded to the BIH for the short MERIT Campaign contained only the results of analysis of McDonald Observatory data. Because of start-up problems at the Australian station during the interval of MERIT, this data set is still in the process of final filtering and data quality analysis. Part of this work of iteration to a final data set was performed at the University of Texas under this contract in cooperation with Dr. Peter J. Morgan of the Australian station. The soft-ware system used and modified under this contract can process multi-station data and the work performed within the contract was included in our original statement of work, i.e., "...Using multi-station LLR data alone, compute values of Earth rotation components (x,y) and UT1..." and therefore satisfy, in part, contract requirements under Task 4 of our original proposal.

3. Intercomparison of LLR Results with Other Techniques

Part of our efforts under this contract stressed some of the quick-turnaround and service oriented requirements of Earth rotation analysis. Therefore we strived to structure our algorithms and data processing systems to satisfy as many of these requirements as possible. Even though, by the expiration date of the contract, we were not able to transmit Earth rotation data products of the best possible quality because of temporary modelling deficiencies at the University of Texas, we were able to put into place all of the operational procedures for accomplishing same. These modelling problems concern mainly the lunar libration situation since we are totally dependent on external sources for this data product. Although efforts are underway both at the Massachusetts Institute of Technology and the Jet Propulsion Laboratory to supply us adequate modelling, such is not yet available. In spite of this, however, as already has been mentioned, preliminary intercomparisons of UT-1 results have been made among the various analysis groups and observing techniques with very good results. Also, within days of contract termination, a file of some 18 months of UT1-UTC information derived from McDonald Observatory LLR data was transferred by the University of Texas at Austin via the General Electric Mark III System to researchers at the U. S. Naval Observatory and the U. S. National Geodetic Survey for intercomparison with other research groups and various observing techniques. The data file transmitted to the USNO and the NGS is included as Appendix B of this report. The file can be supplied in machine-readable form to any and all persons who request it.

Again, even though the data transferred to USNO and NGS consisted of information derived solely from McDonald Observatory LLR data, the entire system as designed and implemented can perform with multi-station data as well. Also, even though funding under this contract has expired, we remain in close contact, and are coordinating in whatever ways we can, with researchers from USNO and NGS to participate in the intercomparison among the various techniques in a scientifically meaningful way. Reports and publications

concerning these studies are expected within the near future. The results reported in this section satisfy, in part, contract requirements under Task 6 of our original proposal.

4. Simultaneous LLR and LAGEOS Data Reduction

Perhaps the most important output product which is a result of this contract and is also the task which received the greatest amount of effort during the term of this contract concerns the creation of a system which has the capabilities of simultaneously reducing LLR and LAGEOS laser ranging observations. Unlike most other studies of this type, we are not primarily interested in combining the Earth rotation results produced from the various techniques. Instead, we are interested in obtaining the Earth rotation parameters from the simultaneous reduction of the actual observational data itself. We feel that this is especially important when we consider both the lunar and the LAGEOS data types. Our study is trying to take advantage of the strong points of each data type and to eliminate, as much as possible, their weak points. We also stress the convenience for performing this task provided by the close proximity of the LLR analysis system within the UT Astronomy Department and the LAGEOS analysis system within the UT Department of Aerospace Engineering and Engineering Mechanics.

As one might expect, the realization of such a reduction system has been fraught with many pitfalls. We have checked out this system with a rather large number of LLR data sets. As of the time of this final report, only two LAGEOS data sets have been made available to us for processing. However, based on only a modest checkout with respect to the LAGEOS data type, I feel that the system can accomplish all that had been planned and that the system can form the nucleus of a more complete system. It is hoped that additional funding will be provided by other means to make full use of this system.

Regular status reports of the evolution of this system were made at the regular semi-annual meetings of the LAGEOS Investigators Meetings which were held at Goddard Space Flight Center. The definitive description of the

present state of this system was presented at the IAU Colloquium No. 63 entitled "High Precision Earth Rotation and Earth-Moon Dynamics, Lunar Distances and Related Observations" which was held in Grasse, France during 22-27 May 1981. A preprint of the presented paper entitled "Earth Rotation from a Simultaneous Reduction of LLR and LAGEOS Laser Ranging Data" by Shelus, Zarate and Eanes is included as Appendix C of this report.

The above-mentioned preprint covers the results of the efforts undertaken herein. The results presented in this section satisfy, in part, contract requirements under Task 5 of our original contract.

5. Administrative Summary

As required under the terms of this contract, monthly financial summary reports, (NASA FORM 533M) were submitted to personell at GSFC (Code 269 and Code 942). Manpower expended during the tenure of this contract includes: Dr. Peter J. Shelus, Principal Investigator (3.6 mm); Dr. J. Derral Mulholland, Research Scientist (2.2 mm); Wen-Jing Jin, Research Associate (3.0 mm); Gary Kern, Research Associate (0.9 mm); Alice Herzog, Clerk-typist (0.75 mm). Trips were made by the Principal Investigator to the semi-annual LAGEOS Investigators Meetings at GSFC and travel support to attend the IAU Colloquium Np. 63 was supplied by this contract. The foreign trip report submitted for that trip is attatched as Appendix D of this report. Finally, as of this writing, one formal publication has been submitted to the open literature, i.e., the paper by Shelus, Zarate and Eanes which is to appear in the Proceedings of IAU Colloquium No. 63.

The Principal Investigator wishes to that his colleagues at the University of Texas at Austin and elsewhere who collaborated on the efforts of this contract and who are too numerous to mention individually. He also wishes to acknowledge the support furnished to him by the GSFC Contracting Officer, Lauria A. Caria and the GSFC Technical Officer, C. C. Stephanides.

APPENDIX A

MERIT UT Results using McDonald LLR Observations at the University of Texas at Austin

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These are UT results computed from McDonald Observatory lunar laser ranging observations at the University of Texas at Austin. Since only single station data is being used, the analysis is similar to that performed by Shelus et al (1). The lunar data set consists of some 63 normal points which represent some 600-700 individual shot-by-shot ranges. Range residuals and partial derivatives are supplied by the standard LLR reduction packages in regular use at the University of Texas.

The LLR residuals are "post-fit", linearized residual and were obtained after a global parameter improvement on 17 months of data approximately centered on the MERIT data set. Parameters in the global solution included linear, annual, and lunar nodal period terms in UT. Linearly interpolated values of BIH Circular D x, y, and UT1-UTC were used. Corrections to the Woolard nutation series, diurnal nutation terms in x and y, and diurnal tidal terms in UT as summarized by Williams (2) here applied. We are presently upgrading our LLR reduction system to more recent treatments of these corrections and the new IAU system of fundamental constants.

An additional note is in order concerning our results. Although a "window width" for observation selection is chosen similar to most other investigations (for instance, when computing 2-day averages, a window width of two days is chosen: all observations falling in that window enter into that particular solution), we do not necessarily slide the window one full window width before performing the next solution. Note that each individual solution is therefore not independent from neighboring solutions. In these results a window width of two days was used and we have slid this window by 0.04 days after each solution. A solution is performed only if there are at least three observations in a particular data set. After sliding the window, a new solution is performed only if the observation set has changed.

(1) Shelus, P. J., Evans, S. W., and Mulholland, J. D.: 1975, in Scientific Applications of Lunar Laser Ranging, ed. J. D. Mulholland, D. Reidel, Co, Dordrecht, P. 201.
(2) Williams, J. G.: 1974, JPL Engineering Memorandum 391-592.

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APPENDIX B

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APPENDIX C

Earth rotation from a simultaneous reduction of LLR and LAGEOS laser ranging data

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+Department of Aerospace Engineering and Engineering Mechanics
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1. INTRODUCTION

As the techniques of lunar and artificial satellite laser ranging mature, emphasis is being placed upon the use of these observations to monitor the Earth's rotation. It is important to note, however, that at the present time neither technique alone can furnish all three components of this rotation to an accuracy which surpasses those results obtained from classical techniques. In the case of LAGEOS laser ranging, unmodeled secular orbital effects couple with axial Earth rotation in such a way that these effects are not separable in the analysis of those observations. In the case of lunar laser ranging, observations have been regularly available only from a single station for the past ten years or so with the result that a change in latitude along the McDonald Observatory meridian is not separable into the ordinary (x,y) components of polar motion. The main purpose of this paper is to present the first stages of an investigation to combine LAGEOS and lunar laser ranging observations. It is hoped that the proper implementation of such a process might eliminate the shortcomings inherent in each technique, while accentuating the advantages of each. This has the potential of producing all three components of the Earth's rotation to an accuracy and precision which is compatible with the present observational uncertainties.

II. DATA AND MODEL COMPATIBILITIES

As is the case in all investigations which seek to combine two different observation types, a great deal of ground work must first be laid before the data synthesis can be begun. Care must be taken to insure that the various data types to be combined are totally compatible and consistent with one another. Not only must such mundane matters as units and formats be unambiguously defined, but standards for such things as reference frames, theoretical and empirical models as well as fundamental and derived constants must be strictly and totally adhered to.

At the University of Texas at Austin, two parallel efforts are underway to obtain Earth rotation information from artificial satellite and lunar laser ranging observations. That within the Department of Aerospace Engineering and Engineering Mechanics has been concerned with the artificial satellite analysis; that within the Department of Astronomy and McDonald Observatory has been concerned with the lunar analysis. Although each has been performing its tasks completely independently of the other, each uses the extensive computing facilities of the University's main computer systems. This happy circumstance has alleviated many of the problems associated with the transfer of data and information between independent reduction and analysis systems. Also, the close proximity of the personnel of both groups assures precise communications and thereby has eased the reference model compatibility problems.

As might be expected, our initial efforts have been applied to testing algorithms and applying them to the LAGEOS and LLR data sets which were obtained during the short MERIT campaign which ran from August through October of 1980. The lunar data set consists of some 63 normal points which represents some 600-700 individual lunar laser ranging observations. Specific information about this data set can be found in the MERIT Campaign Report which should be generally available from the Bureau Internationale de l'Heure in Paris. The LAGEOS data set contains in excess of 20,000 individual LAGEOS ranges and will be described elsewhere. In both cases, our analysis efforts are concerned with range residuals and partial derivatives which are supplied by the standard LLR and LAGEOS reduction packages which have been in regular use over the past few years at the University of Texas. Although, to the best of our knowledge, the current data sets are internally consistent and compatible, additional checks will be made continuously throughout the course of the total investigation to preserve and/or extend this integrity.

III. ANALYSIS TECHNIQUES

Because of the short term nature of the effects being sought by this investigation, our "observational equation" is a simple one and, for the LLR case, is similar to that presented by Stolz and Larden (1976), i.e.,

$$\begin{aligned} \rho_O-\rho_C = {} & r\ [\ \sin\phi \cos\delta \cos(\lambda-H) - \cos\lambda \sin\delta \cos\phi\ ]\ x \\ & -r\ [\ \sin\phi \cos\delta \sin(\lambda-H) - \sin\lambda \sin\delta \cos\phi\ ]\ y \\ & +r \cos\phi \cos\delta \sin H\ \delta(\mathrm{UT1-UTC}) \end{aligned}$$

where $\rho_O-\rho_C$ is the range residual (observed minus computed); r is the radius of the Earth and λ is its east longitude; H is the local hour angle of the retroreflector and δ is its declination; x, y, and δ(UT1-UTC) are improvements to the nominal values of these Earth rotation parameters. Although the above expression is that which is

specifically used for LLR, a similar one has been used for the LAGEOS case.

This investigation is seeking values for the Earth rotation parameters averaged over 5 day intervals or less. In the case of LLR these short-term effects are well-separated from any unmodelled long term effects because it is believed that all short term (less than two weeks or so) lunar orbital and librational effects down to the few centimeter level are known. This is, of course, not yet the case for LAGEOS and it is certainly recognized that analysis efforts to extract orbital information from the LAGEOS data also extract axial Earth rotation information from that data, thus decreasing one's ability for obtaining accurate UT1-UTC information from this data type. It is believed that this study is the first attempt to obtain Earth rotation parameters by the simultaneous reduction of LLR and LAGEOS data at the observation level.

The LLR residuals which were used in this study are "post-fit", linearized residuals having been obtained after a normal global parameter improvement run on some 17 months of data centered approximately on the MERIT data set. Parameters in the global solution runs include linear, annual and lunar nodal period terms in UT. Linearly interpolated values of smoothed BIH Circular D x, y, and UT1-UTC which were modified by corrections given by Williams (1974) based on McClure (1973) have been used. Also used was the Woolard (1953, 1959) nutation series as modified by Melchoir (1971). Simple checks have shown slight differences with the Wahr (1980) nutation series and the Yoder et al (1981) treatment of UT diurnal tidal terms, although we are presently upgrading our LLR reduction systems to these more recent treatments and the new IAU system of fundamental constants.

The LAGEOS residuals were computed with the model used to generate the LAGEOS long-arc trajectory designated LLA80.11. The gravity field used was LGM80.11.1; this geopotential is a preliminary LAGEOS-derived adjustment to the GEM10 field. The model includes the Wahr nutation series, the short period variations in UT from Yoder et al (1981), and BIH Circular D smoothed values for polar motion and UT1. The station positions were the LAGEOS-derived set designated LSC80.11. Orbit initial conditions were estimated from a sampled set of LAGEOS observations from 16 sites over the 124 day period from 30 June to 31 October 1980 (MJD = 44420-44543). The full set of data contained 508,000 observations while the sampled set, obtained by requiring that no two observations from any one site be less than one minute apart, contained 22,000 ranges. The unweighted RMS of the post-fit residuals was 0.42m. The estimated "single-shot" precision was 0.25m when averaged over all of the laser systems involved.

The remaining unmodelled long-period variations in the LAGEOS orbital elements were removed by smoothing the element residuals

from LLA80.11 with a Vondrak filter using ϵ=1.0E-06 (half power at 60 days). Because of the high correlation of errors in UT and errors in the LAGEOS orbit node, this empirical adjustment to the LAGEOS orbital elements effectively filters a portion of any signal present in UT1-UTC. The small correlation of polar motion components x and y to the orbital elements implies that they are only slightly affected by the empirical adjustment. As the LAGEOS dynamical model matures the use of an empirically corrected orbit will be discontinued.

IV. NUMERICAL RESULTS

Using an observational equation of the type give in Section III, we have computed observational residuals and partial derivatives using standard lunar and LAGEOS data analysis packages. Several of the initial solution attempts are being reported here. To assess the solution algorithms of this package the first solution run was performed to obtain UT1-UTC and a constant bias from LLR observations alone. Since only single station LLR data is being used in this study the analysis is similar to that performed by Shelus et al (1976). The second solution run was performed to obtain x, y, and UT1-UTC estimates from LAGEOS observations alone. Only those LAGEOS observations which were close in time to LLR observations were used (a full analysis of the LAGEOS-only results is beyond the scope of this paper). Each of these two runs provided results which were similar to those obtained from analyses performed independently of this study. The results, which give deviations to BIH Circular D 5-day smoothed values, can be seen for UT1-UTC in Figures 1 for the LLR-only case and for x, y, and UT1-UTC in Figure 2 for the LAGEOS-only case.

From an examination of these figures we see that our initial expectation that UT1-UTC "power" has been lost from the LAGEOS observations is confirmed since the deviations from BIH values for UT1-UTC are much smaller from the LAGEOS-only results than from the LLR-only results. This assumes, of course, that the LLR-only results are "correct". Having confirmed our expectations, we next proceed to the next step whereby we may "tie" the short-term signature from the LAGEOS data type to the long term signature from the LLR data type by attempting simultaneous solutions. Figure 3 shows the results for our first such attempt. In this case we have opted to only consider the x and y partial derivatives (not UT1-UTC) from the LAGEOS data set simultaneously with all three partial derivatives (x, y, and UT1-UTC) from the LLR set. All observations going into the solutions are given equal weight in spite of the overwhelming amount of LAGEOS data with respect to the LLR data. The signature for the UT1-UTC results are similar to the LLR-only results, and the signatures for the x and y results are similar to the LAGEOS-only results, as would be expected.

A very important sidelight of this investigation surfaces from our

processing of the observations in a manner different from most. Although a "window width" is selected similar to most other investigations (for instance, when one is computing two day averages, one chooses a window width of two days; all observations which fall through that window are allowed to enter into that solution), we do not necessarily move our window one full window width before performing the next solution. We feel that this technique can give a more complete representation of the information content of each data set. However it does have the drawback that each individual solution run is not completely independent from neighboring solutions. In all of the results which are presented here we have used a "window width" of two days and have "slid" this window by 0.04 days after each solution. A solution is performed only if there are at least three LLR observations in a particular data set. After sliding the window, a new solution is performed only if the LLR data set has changed.

The results presented in Figure 3 are not satisfying from several points of view. First, there were no attempts made to normalize the effects of each observation type through proper weighting parameters. As has already been mentioned, the LLR data are normal points while the LAGEOS data are shot-by-shot data. A far more serious objection arises from the fact that only a very weak tie is established between the two data types because the UT information from the LAGEOS data has been ignored and only single station LLR data exists. A crude attempt at normalization was made for the fourth solution run (Figure 4) wherein the third solution was performed again except that the LLR normal points were given a weight 5.0 with respect to unity for the LAGEOS shot-by-shot points. As might be expected, Figures 4 and 5 are quite similar.

V. DISCUSSION

Although the results presented here are preliminary, they are indicative of the great progress which has been realized recently at the observation by observation level in the combination of LAGEOS and LLR results for Earth rotation. Each technique is certainly mature enough that consistency and compatibilty between such different data types has been accomplished. The presence of such a two-pronged analysis effort opens the door to a more proper and satisfying data synthesis. Our next steps will progress to more realistic ties between the two data types. This will entail using the LLR results to help separate the unmodelled orbital effects of LAGEOS from axial Earth rotation instead of merely ignoring the effects of UT1-UTC in the LAGEOS data. Simultaneously the x and y results from LAGEOS will be used to improve the LLR results. Once separation is obtained the short term LAGEOS results will be "anchored" by the long-term LLR results, thereby giving the UT1-UTC parameter the same significance and resolution as the x and y parameters.

Further progress will be also accomplished by a further investigation of the relative weighting schemes for LAGEOS versus LLR data to more reasonably combine normal point and shot-by-shot data. It may be also attempted to work with LLR shot-by-shot data and/or LAGEOS normal point data to obtain this next level of compatibility.

VI. ACKNOWLEDGEMENTS

This work has been supported in part by National Aeronautics and Space Administration Contracts NAS5-25898 and NAS5-25991 to the University of Texas at Austin.

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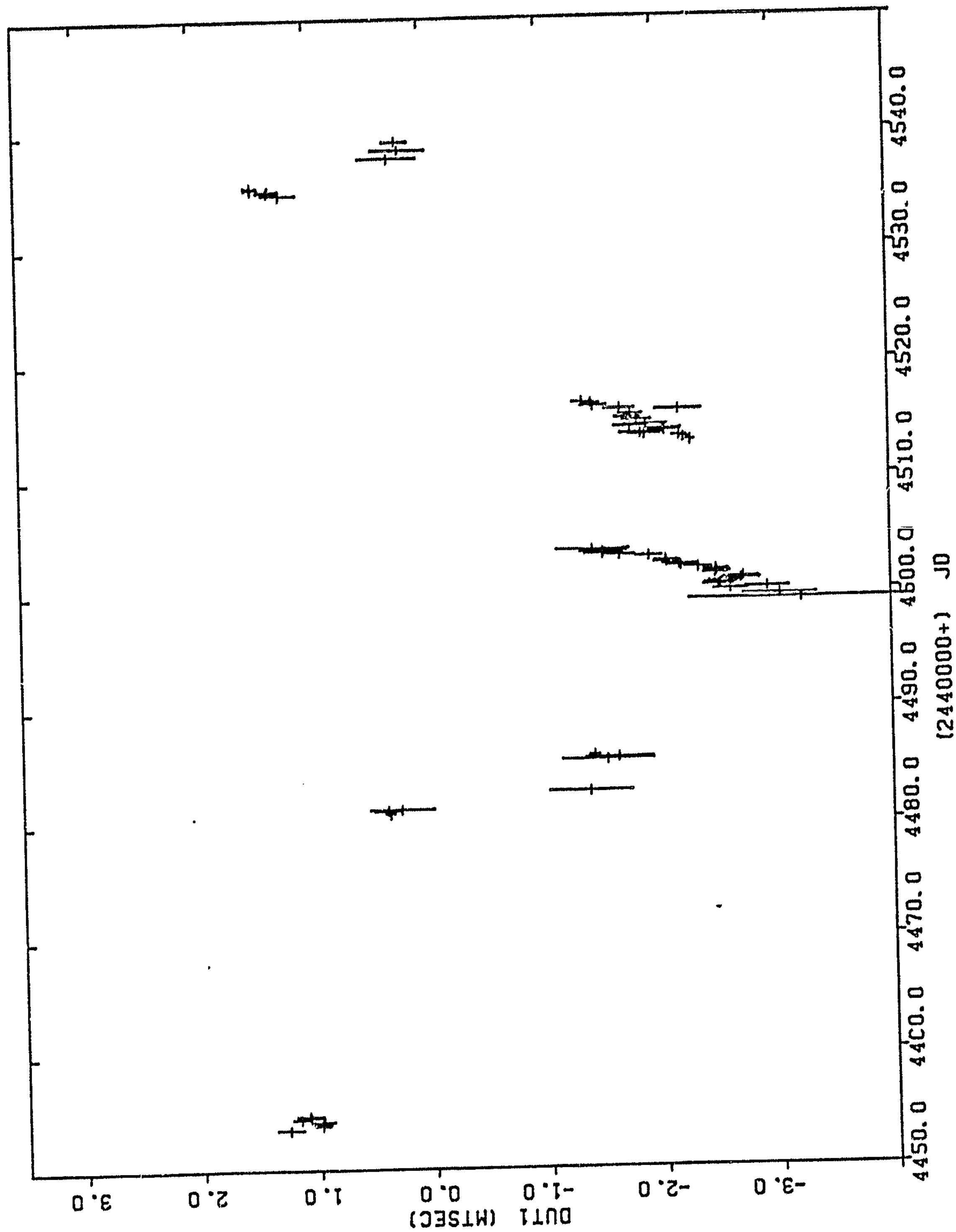
Figure Captions

Figure 1. Differences in UT1-UTC determined by LLR with respect to BIH Circular D 5-day smoothed values.

Figure 2. Differences in x, y, and UT1-UTC determined by LAGEOS with respect to BIH Circular D 5-day smoothed values.

Figure 3. Differences in x, y, and UT1-UTC determined by LLR and LAGEOS with respect to BIH Circular D 5-day smoothed values (LAGEOS sampled shot-by-shot data and LLR normal point data equally weighted).

Figure 4. Differences in x,y, and UT1-UTC determined by LLR and LAGEOS with respect to BIH Circular D 5-day smoothed values (LLR normal point data weighted by a factor 5 with respect to LAGEOS shot-by-shot data).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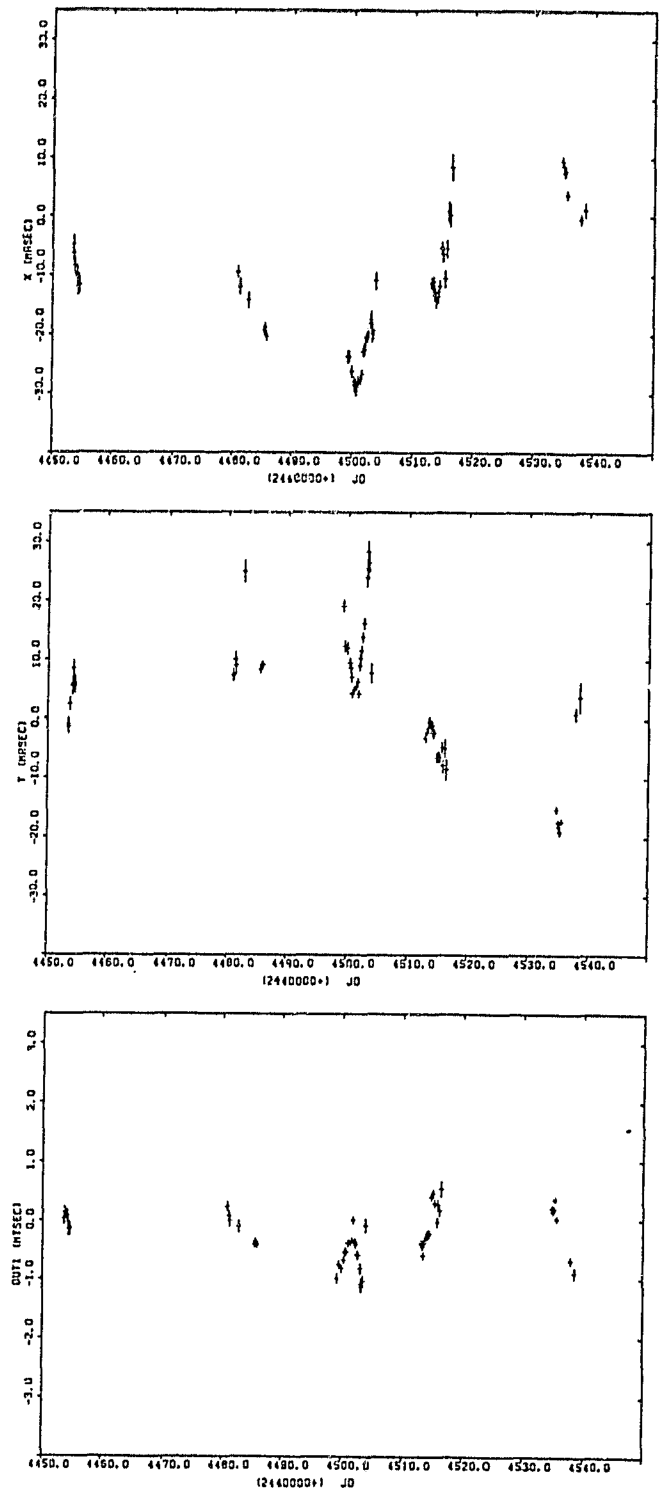
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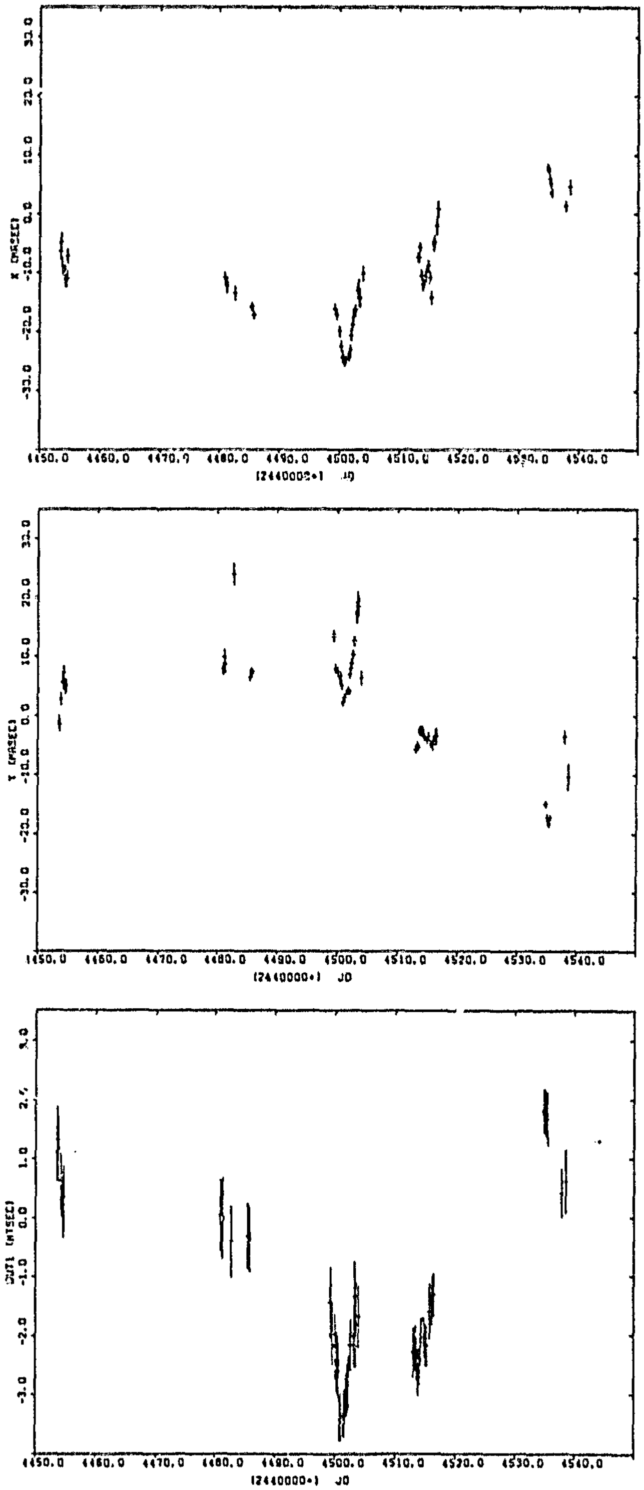
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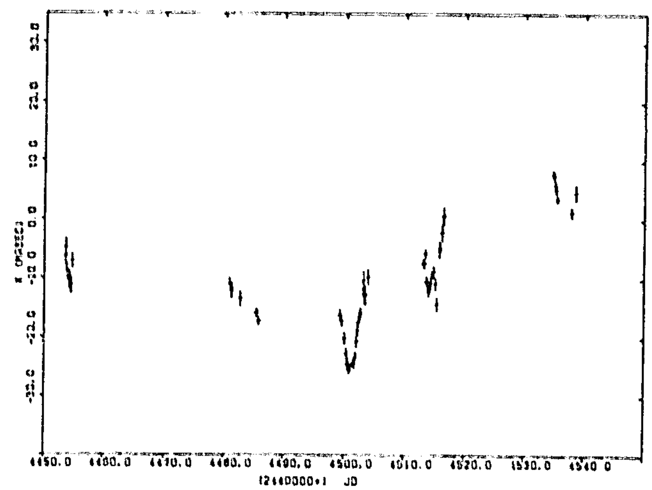
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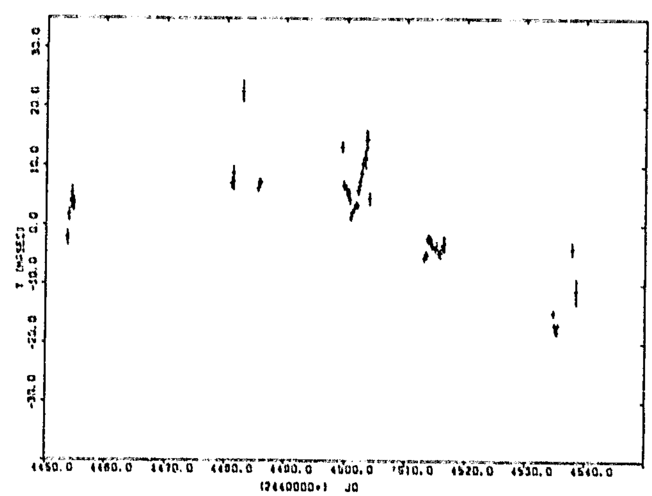
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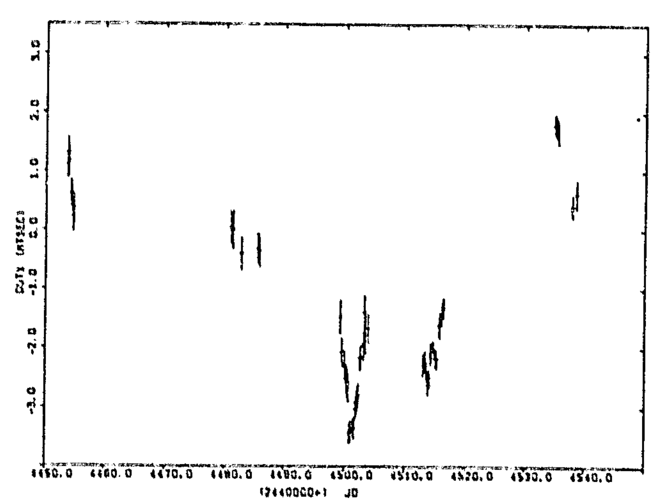
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APPENDIX D

THE UNIVERSITY OF TEXAS AT AUSTIN
COLLEGE OF NATURAL SCIENCES
Department of Astronomy
AUSTIN, TEXAS 78712

Date: 2 June 1981

MEMORANDUM

To: C. C. Stephanides (Code 904) and L. E. Walker (Code 269)

From: Peter J. Shelus P.J.S.

Subject: Foreign Travel Trip Report (Contract NAS5-25898)

During May 18-21 I attended the Project Merit Workshop which was held in Grasse, France. This workshop was held under the auspices of the IAU/IUGG Joint Working Group on the Rotation of the Earth.

Informal sessions were held among participants on Monday morning. On Monday afternoon brief formal summary reports were presented by the directors of the various observation, analysis, computing and communication centers. These summary reports were mainly concerned with what went right and what went wrong during the short MERIT campaign. A short discussion on changes which might be recommended to insure a successful long campaign followed.

The entire day Tuesday was dedicated to expanded reports on the short MERIT Campaign from the various technique coordinators and their sub-coordinators. During these sessions I presented a report on the McDonald Observatory participation in the short MERIT campaign. The report summarized the data acquisition and data communications tasks which were accomplished.

Formal reports continued into Wednesday. I also attended meetings of the MERIT Standards Committee chaired by W. G. Melbourne, the lunar laser ranging sub-group for MERIT chaired by J. D. Mulholland and the EROLD Steering Committee also chaired by Mulholland. Topics related to LLR were related to the modelling standards which would be used during the regular MERIT campaign. Most crucial to LLR are of course the lunar orbit and rotation models. Along those lines I was assigned the action item of communicating with appropriate individuals and submitting a final report to the MERIT Standards Committee by October 1981 with LLR recommendations.

A General discussion on the short MERIT campaign and a review of aims and tasks for the regular campaign occupied us on Thursday. Of most importance for LLR was the decision to separate LLR and SLR. During the short campaign Aardoom and Mulholland were subcoordinators for the artificial satellite and lunar techniques respectively under Silverberg. For the main campaign O. Calame (of CERGA) will be the

coordinator for the LLR technique while J. Lattimer (of SAO) will be the coordinator for the SLR technique. There will be no "overall" coordinator for the laser techniques. A final decision was to hold the regular MERIT campaign from September 1, 1982 through October 31, 1983.

In summary, it was generally accepted that most of the goals of the short MERIT campaign were successfully attained. Each of the techniques were able to observe, reduce and transmit Earth rotation information to the Coordinating center at BIH in a timely manner. The use of the electronic transfer of information was of great importance. However, a significant amount of cooperation and communication will need to be exercised to assure the efficient and economical use of the system during the up-coming long MERIT campaign. A sub-group consisting of Peter Morgan, Jim Lattimer, Martine Feissel and myself were assigned the task of looking into these matters.

Finally, it was acknowledged that the short MERIT campaign also formed the incentive for many of the techniques to come "up to speed" earlier than they might have under ordinary circumstances. The effect of the Chinese classical data did much to improve the results of that technique. We are all looking forward to an equal success of the regular campaign.

On Friday, May 22 and Monday through Wednesday, May 25-27, I attended the sessions of IAU Colloquium No.63 entitled "High Precision Rotation and Earth-Moon Dynamics, Lunar Distances and Related Observations" at Grasse, France.

Friday served as a transition day as the MERIT Workshop wound down and the Colloquium commenced. A total of 12 papers were presented on Friday which summarized the scientific results which were obtained by the various observational techniques for Earth Rotation monitoring during the short MERIT technique. I presented a paper as this session which was entitled "Earth Rotation from a Simultaneous reduction of LLR/LAGEOS Data".

On Monday 4 papers were presented in the morning which supplied historical and complimentary material related to the concepts of Earth rotation monitoring. The afternoon was spent in a meeting of the EROLD Steering Committee. This meeting was essentially a continuation of that begun by the LLR group during the MERIT Workshop the previous week. Mainly discussed were the relations, if any, which should be eliminated, maintained or inaugurated between the EROLD and the MERIT campaigns.

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2 June 1981

Tuesday and Wednesday saw a total of 18 papers being presented on many of the aspects of lunar dynamics. These papers ran the gamut from energy dissipation, tidal friction and relativistic perturbations to analytical and semi-analytical theories of the Moon as well as reference frame determinations.

I returned to the U.S. on Thursday, 28 May 1981.

PJS/ah